

Research Note 82-13

DEVELOP AND EVALUATE NEW TRAINING AND PERFORMANCE
SYSTEMS FOR MAINTENANCE JOBS EVALUATION:
FINDINGS, PLANS, AND EXAMPLES

Walter R. Harper and James C. Gutman
ANACAPA SCIENCES, INC.

TRAINING TECHNICAL AREA



U. S. Army

Research Institute for the Behavioral and Social Sciences

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In work completed prior to the final year, a prototype MPS was developed and operated by the contractor staff. Maintenance managers reported that the MPS provided useful, unique, and valid information to aid maintenance operations. During the 46-week period in which the prototype system was operated at Fort Carson, Colorado, the relationships among maintenance workload, efficiency, and skill were studied. As workload increased, efficiency decreased. However, changes in skill levels, through personnel turbulence and/or training, mediated between workload and efficiency. For example, efficiency might actually increase with increased workload, if skill levels increased as well. This finding supported the underlying premise of the MPS, that effort expended on increasing maintenance skills would pay off in increased maintenance effectiveness.

The final year produced a streamlined and expanded MPS that could be handed over to and operated by Army personnel. The system encompassed 10 technical Military Occupational Specialties (MOS's) and the equipment of a mechanized infantry division. The system was proven during a 10-week implementation period at Fort Carson, Colorado. Also, a study of MPS potential in geographically dispersed operations, such as in USAREUR, concluded that the MPS would operate satisfactorily if data collection from outlying units were coordinated with maintenance control system procedures.

A total of 34 reports, manuals, system descriptions, and performance aids were prepared and submitted during the three-year project. These publications provide details on the project and the resulting MPS.



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INTRODUCTION

This special report is the last in a series of reports submitted over three years to describe progress and results of contract (MDA-903-78-C-2007) entitled "Develop and Evaluate New Training and Performance Systems for Maintenance Jobs." The work was done for the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI).

The purpose of the work was to enhance unit-level maintenance training by providing a maintenance performance system (MPS) for use by maintenance management and supervisors. The system was developed with a capability of diagnosing management and training problem areas in DS-level maintenance. The MPS has an additional capability of prescribing specific training priorities and resources as corrective measures. The sequence of "milestone" steps in MPS development is shown in Figure 1.

The work statement for this project required that an evaluation component be included as part of the development of any new maintenance training and performance system. This report addresses that topic.

Evaluation is described below under three major headings:

- Analysis of MPS data from two similar direct support companies for a 46-week period.
- Key points to note when installing an evaluation program for MPS in other CONUS/USAREUR locations.
- Benefits possible from MPS use in exemplary situations.

ANALYSIS OF PROTOTYPE MPS DATA

The MPS was developed to improve direct support maintenance effectiveness. Effectiveness is defined as a function of the interaction of shop efficiency, work-force productivity, and job quality as shown in Figure 2. The driving force behind effectiveness is command emphasis on management and training, translated into actions for change.

Information nurturing command emphasis and subsequent action is provided in MPS reports. The development of MPS was therefore planned to improve

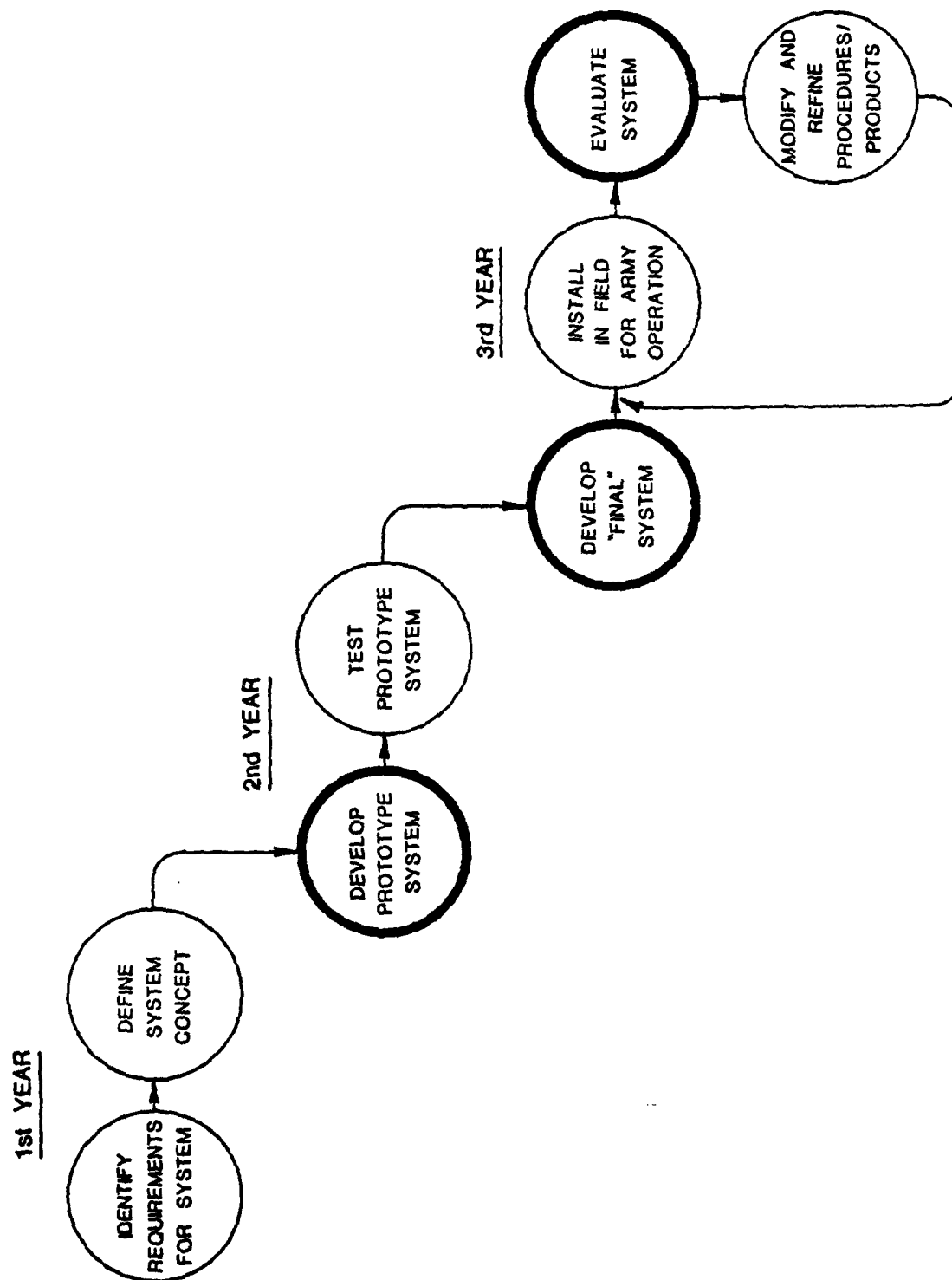


Figure 1. Sequence of "milestone" steps in MPS development.

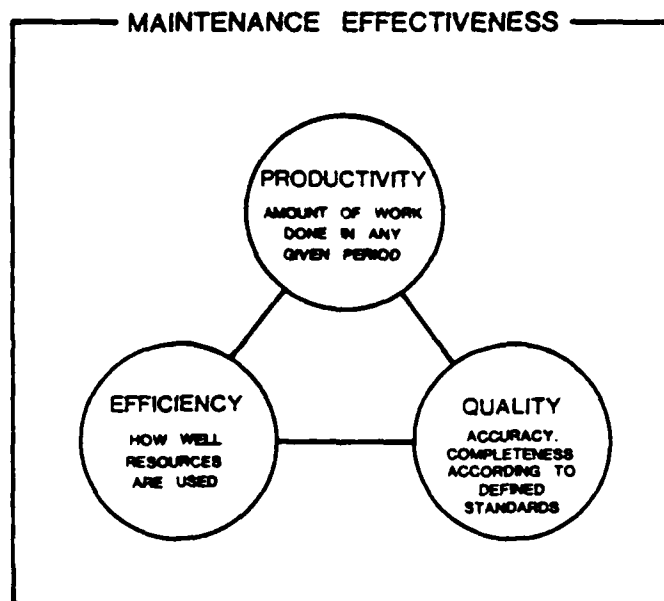


Figure 2. Interaction of base components governing maintenance effectiveness.

command's ability to take action based on reported data. Year One, for example, demonstrated the feasibility of collecting maintenance data and summarizing them in a format for aiding management and training decision-making. Year Two was focused on expanding the concept and providing more descriptive detail and breadth of maintenance problems in selected technical areas. The third year provided an MPS complete and advanced enough to meet the initial objectives.

But during the second year a wealth of descriptive data became available on results of shop procedures, work-flow, and job experience. We have analyzed these data with the objective of identifying change over a 46 week period—not only within each DS company but also differences between two similar DS companies as reflected in MPS reports.

Because of the fluctuating nature of maintenance performance data reflected in MPS reports, **time-series analyses** were chosen as the most productive analytical technique for the set of data under investigation. The major components of a time series are present to a high degree in the data. They include secular

(long-term) trend, seasonal variation, cyclical variation and irregular (erratic) variations.

The time series provided a way of identifying changes in the parameters of maintenance effectiveness shown by fluctuations in the data. Since 23 x 2-week periods were plotted, variations were easily observed and may be considered as transients in the plotted patterns. Fitting a linear trend line to the data points using visual estimation was difficult because of these variations. Accordingly, the least squares method was used to fit the trend line more precisely. (Missing data points in each time series were handled by substituting the grand mean of the series for the missing data.)

An examination of MPS reports resulted in selection of specific tables in the major areas of Shop Efficiency and Repairmen's Skill. Least-squares fitted trend lines were developed for 40 time-series graphs. Subsequent examination showed that the most promising reports for demonstrating the feasibility of MPS responsiveness to changing shop conditions and training needs were those listing total direct man-hours expended, percentage of growth (skill) index, and average direct man-hours per job. The specific tables reported on in the analysis results are referenced by MOS and DS company in Table 1.

In the RESULTS section which follows, the figures show the time series of **average direct man-hours per job** from all jobs being tracked in DS companies with the data points and the least-squares derived trend lines. A tentative hypothesis based on these data was that as skill increased so should the average direct man-hours per job decrease.

The time series of **total man-hours expended in two-week periods** (also listed in the figure by each MOS tracked in each company) suggested a tentative hypothesis that less MOS man-hours would be needed to fulfill work needs over selected periods where job totals were held constant but skill levels increased.

The **Growth (Skill) Index** for each MOS as a group was included to provide a basis (in two-week increments) for comparison with trend lines plotted on other time-series charts. The hypotheses formulated previously related skill index (shown as a total for an MOS by two-weekly periods) to measures of shop efficiency.

TABLE 1
LISTING OF TIME SERIES GRAPHS REFERENCED BY MPS SOURCE AND TITLE

MPS Source (Table Number)	Time Series Descriptor	DS Company Ref.
9a, 9b, 9c	Growth (Skill) Index for all MOS 63H (Automotive) Repairmen	C, E
10a, 10b, 10c	Growth (Skill) Index for all MOS 41C (Fire Control) Repairmen	C, E
11a, 11b, 11c	Growth (Skill) Index for all MOS 45K (Turret) Repairmen	C, E
12a, 12b, 12c	Growth (Skill) Index for all MOS 45L (Artillery) Repairmen	E
6	Average direct man-hours per auto- motive job done by MOS 63H Repairmen	C, E
6	Average direct man-hours per fire control job done by MOS 41C Repairmen	C, E
6	Average direct man-hours per armament job done by MOS 45K Repairmen	C, E
6	Average direct man-hours per artillery job done by MOS 45L Repairmen	C, E
1	Total direct man-hours expended in two- week periods by all MOS 63H	C, E
2	Total direct man-hours expended in two- week periods by all MOS 41C	C, E
3	Total direct man-hours expended in two- week periods by all MOS 45K	C, E
4	Total direct man-hours expended in two- week periods by all MOS 45L	C

ANALYSIS RESULTS

As noted previously, the time series data illustrated secular (long-term) trends and irregular and cyclical variations. The long-term trends are best understood by observing the fitted linear trend lines. The response of the maintenance performance system to irregular variations, which can be caused by events such as large-scale maneuvers, personnel transfers, and similar events outside the control of the shop, can best be understood by studying variations in the data over short time periods.

We have developed several conclusions regarding the interrelationships among the measures charted in the time series. The interrelationships are discussed in terms of the association of total direct man-hours expended with changes in average direct man-hours per job and the skill growth index.

Total direct man-hours expended in any two-weekly time period represented shop workload for that same period (for a specific MOS). The skill growth index mentioned above was a composite measure which represented the average skill level for repairmen in a specific MOS. The average direct man-hours per job reflected one measure of a specific MOS group's effect on shop efficiency.

The results of the time series analyses described the interaction of workload with changes in shop efficiency and with skill levels.

The capability of the MPS to reflect change in maintenance performance and practices was illustrated by these findings derived from analysis of the time-series charts.

- The strongest interaction appears to be between **total direct manhours** (shop workload) expended over the 46 weeks in the data sample, and **average direct man-hours per job** (time per job).
- **Shop workload** trend lines showing a sharp linear rise are strongly related to a decrease in shop efficiency (i.e., **average direct manhours per job** increased).
- The level of repairman's skill (**Skill Index**) has a strong influence on the interaction of the two measures described above.
- When level of skill increases (**skill index**) it slowed the rate of increase of **average direct man-hours per job** that was associated with a large increase in workload.

- Radical changes in period-to-period data (i.e., short-term variations considered as "transients" in the normal cycle) for the level of repairmen's skill (**skill index**) were associated with increases in **average direct manhours per job**.

The discussion below centers around interpretation of the MPS trend data which led to the findings listed above. The discussion is organized into two convenient categories dealing with large increases in shop workload and small increases in shop workload. Appropriate figures are cited throughout the discussion to aid the reader.

Large Increases in Shop Workload

It was noted that as shop workload increased so did the average time taken to do a job. But the **amount** of the increase in job time was mediated (i.e., enhanced or modified) by the trend of the appropriate (to the MOS and task) skill index.

Using MOS 45K (Turret repairman) "C" Co., as an example, consider the trend line increase of shop workload (direct man-hours expended) in Figure 3. The least squares analysis for fit of the trend line placed the source (February 1980)* at four hours and the end (December 1980)* at 270 hours.

The skill index (shown as a percentage) trend line for the same period (Figure 4) rose from 40% to 58%. The average hours per job trend line (Figure 5) showed that the trend for job times almost doubled (i.e., from 6.5 to approximately 13 hours).

The conclusion here (from the MPS data) is that heavy workload tends to increase job times, possibly because of increased pressure, dilution of available resources, and reduction of needed supervision. But if repairmen have higher skill levels and can do the work faster with fewer errors and reduced need for supervision, then the increase in job times will be reduced.

This set of hypotheses has some support in parallel data from "E" Company for the same MOS and time period.

*Time periods referred to are constant throughout the discussion and encompass all examples cited.

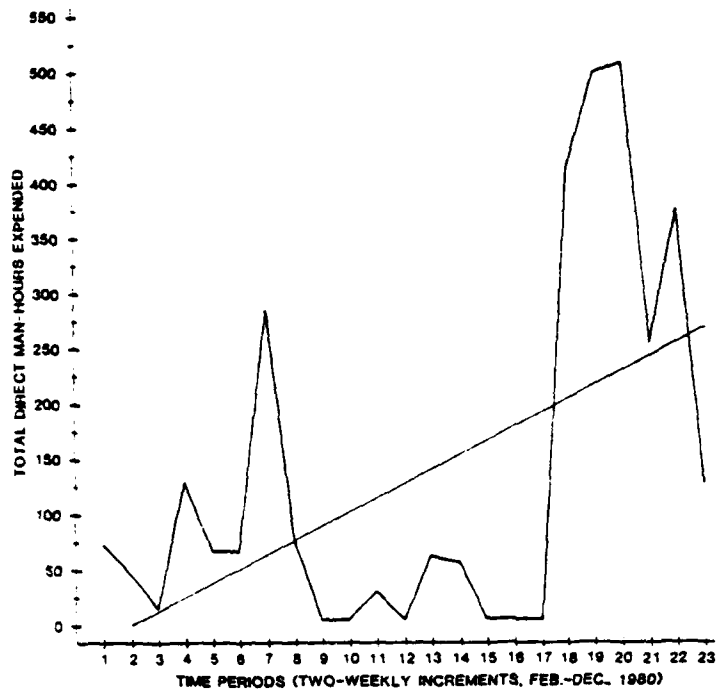


Figure 3. Total direct man-hours (shop workload) for MOS 45K ("C" Company).

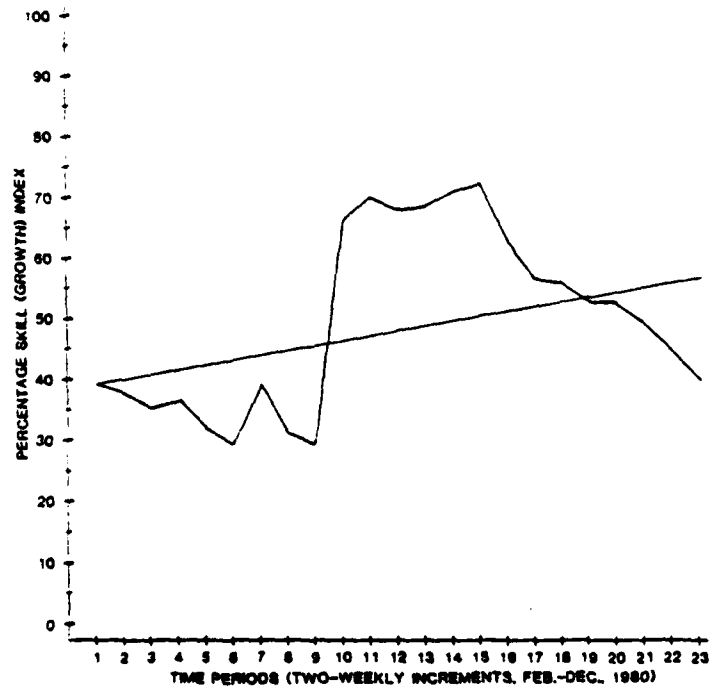


Figure 4. Skill (growth) index shown as percentage growth for MOS 45K ("C" Company).

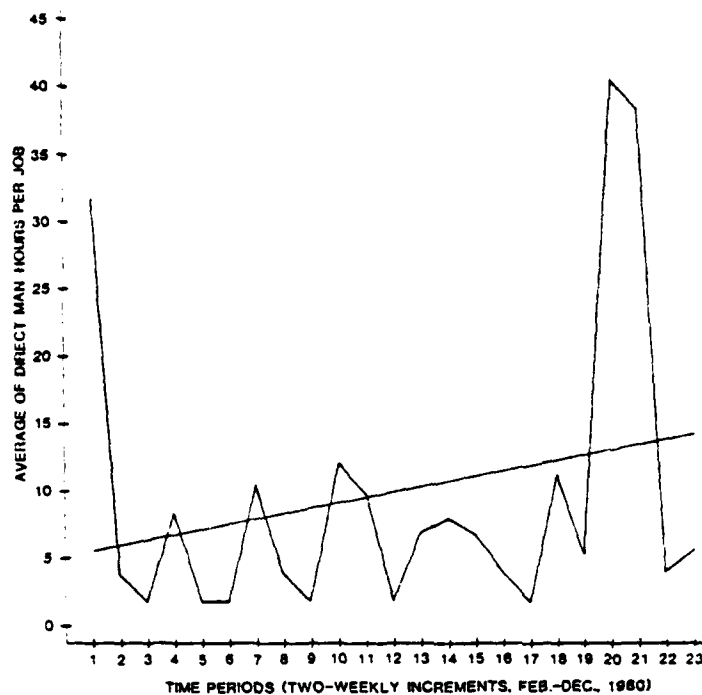


Figure 5. Average direct man-hours per job for MOS 45K ("C" Company).

Note in Figure 6 that the trend line for total direct manhours (shop workload) showed an even greater rate of increase than that for "C" Company. Also note that the skill index trend line (Figure 7) has a negative slope. That is, the level of skill declined from a source of 50 percent in February to 35 percent in December.

As expected, the average direct manhours per job trend line (see Figure 8) also rose over the period. But because the skill level trend line *declined*, the increase in the trend line for time taken to do the job climbed from an average of 2 hours to approximately 6.8 hours per job at the end of the period—a threefold increase.

The same pattern was noted from an analysis of transients (periodic peaks, dips in the actual data points plotted for the trend line analysis). Note for example, the peak in shop workload (total direct man-hours expended for MOS 45L (Artillery repairman) tasks done in "C" Company between time periods 3-5 (see Figure 9). Compare this peak with the almost parallel transient point that occurred between the same time periods (Average direct man-hours per job) as shown in Figure 10.

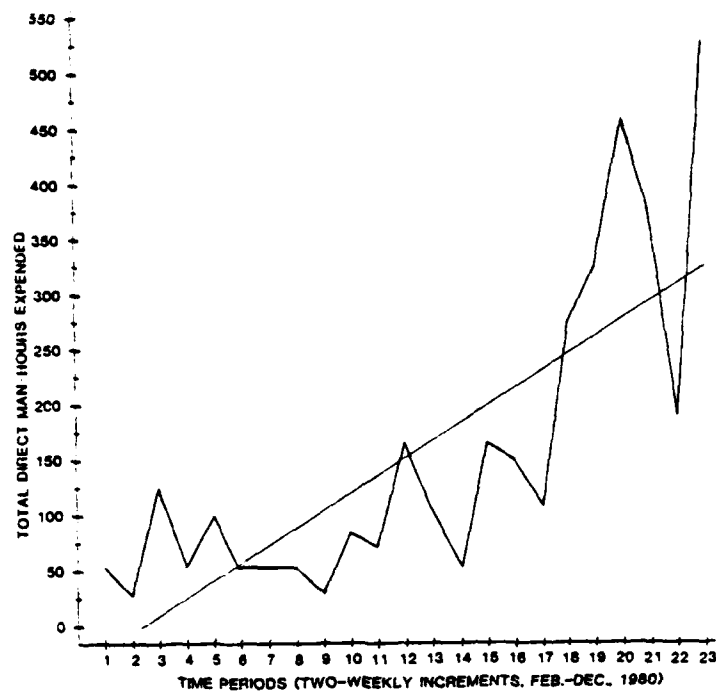


Figure 6. Total direct man-hours (shop workload) for MOS 45K ("E" Company).

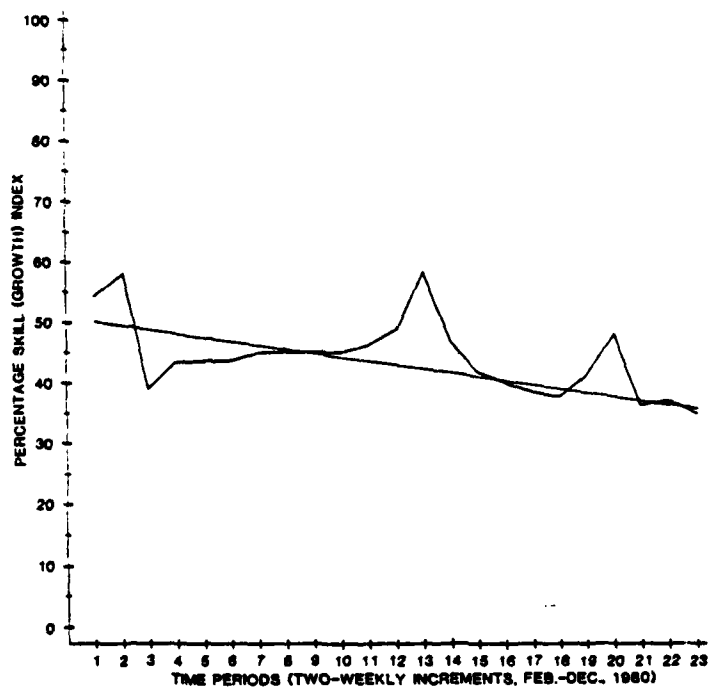


Figure 7. Skill (growth) index shown as percentage growth for MOS 45K ("E" Company).

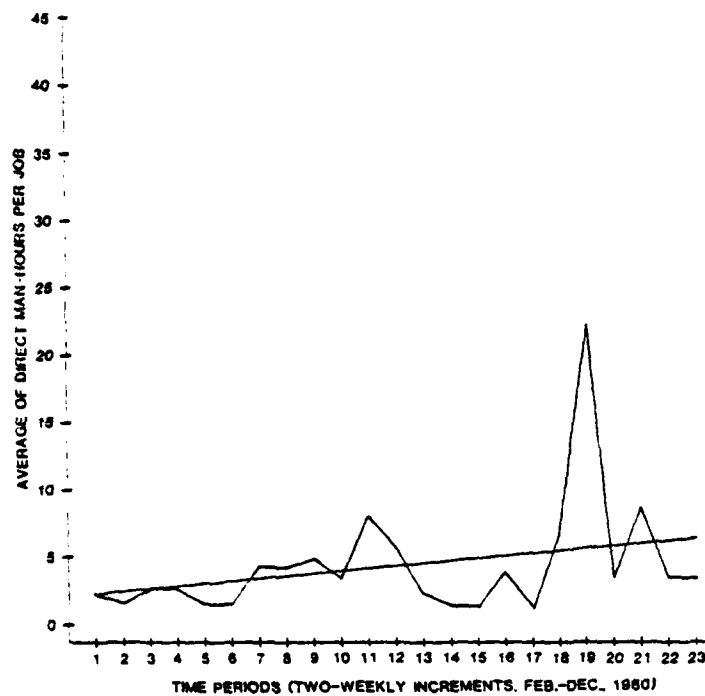


Figure 8. Average direct man-hours per job for MOS 45K ("E" Company).

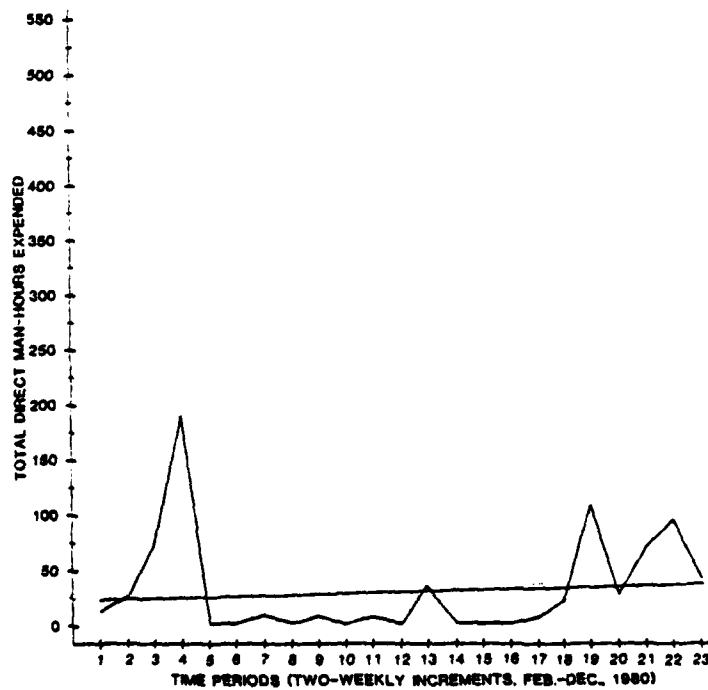


Figure 9. Total direct man-hours (shop workload) for MOS 45L ("C" Company).

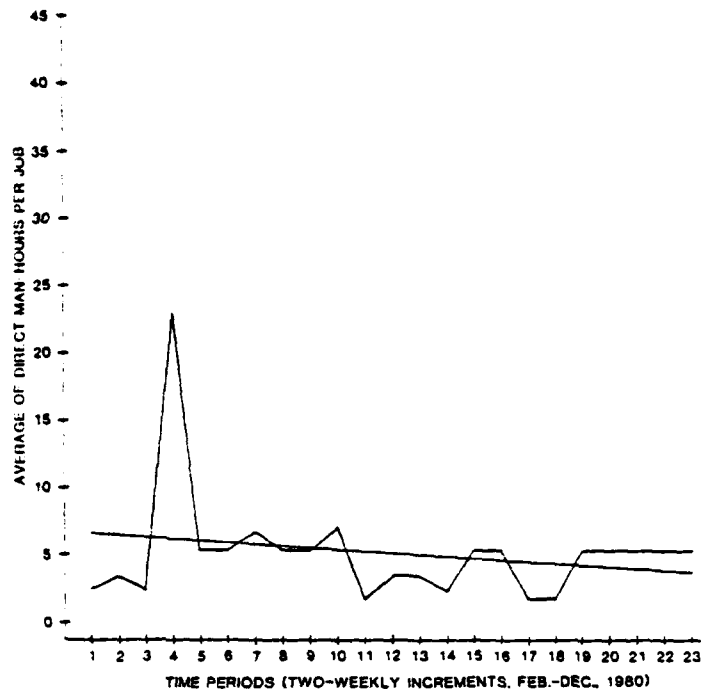


Figure 10. Average direct man-hours per job for MOS 45L ("C" Company).

The conclusions are summarized and shown graphically in Table 2.

TABLE 2
SYMBOLIC REPRESENTATION OF INTERACTION AMONG
MEASURES FROM INCREASED WORKLOAD OF
MOS 45K (TURRET REPAIRMAN) TASKS

COMPANY	SHOP WORKLOAD	SKILL LEVEL	AVERAGE TIME PER JOB
"C" (Figs. 4, 5, 6)	▲▲▲*	▲	▲
"E" (Figs. 6, 7, 8)	▲▲▲	▼	▲▲

*KEY ▲▲▲ : Large percentage increase
 ▲▲ : Medium percentage increase
 ▲▼ : Small percentage increase/decrease

Smaller Increases In Shop Workload

The relationship described above can be illustrated even more vividly by examining trend lines showing relatively shallow rises in shop workload.

Tasks done by MOS 41C (Fire control repairman) in "C" Company show a minor increase in the workload trend line from 15 hours at the source of the trend line to 45 hours at the end (see Figure 11). Level of skill (See Figure 12) trend line remained constant over the period. The trend of the average time to do a job as shown in Figure 13 increased slightly (from 3 hours to approximately 4.3 hours).

When parallel data for "E" Company is examined, note that the shop workload trend line (Figure 14) ranges from 38 hours to approximately 75 hours.

The level of skill (skill index) trend line shown in Figure 15 increased by an approximate factor of three (i.e., from 26 percent to 73 percent). But the average time taken to do a job shown in the trend line in (Figure 16), declined by almost 50 percent (i.e., from 3 to 1.5 hours). The point here (the "C" Company example) is that if shop workload shows a modest increase and skill levels are constant,

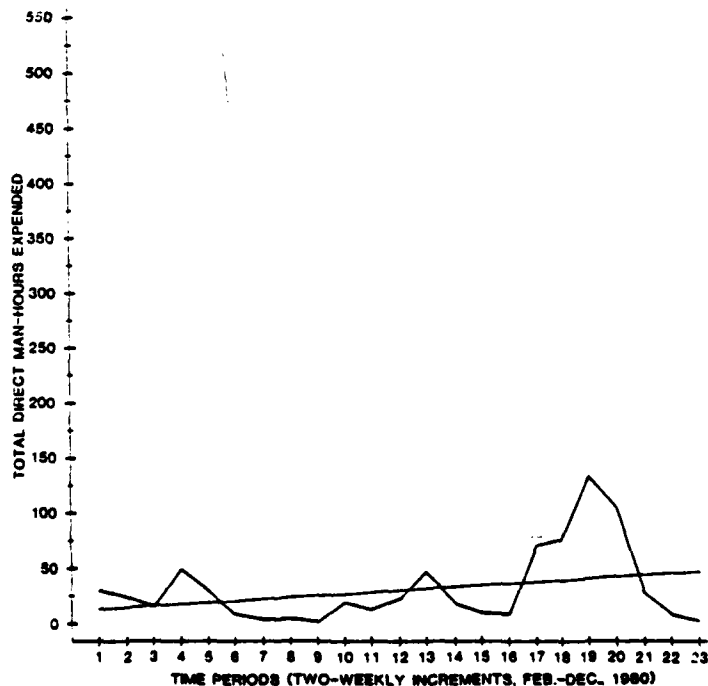


Figure 11. Total direct man-hours (shop workload) for MOS 41C ("C" Company).

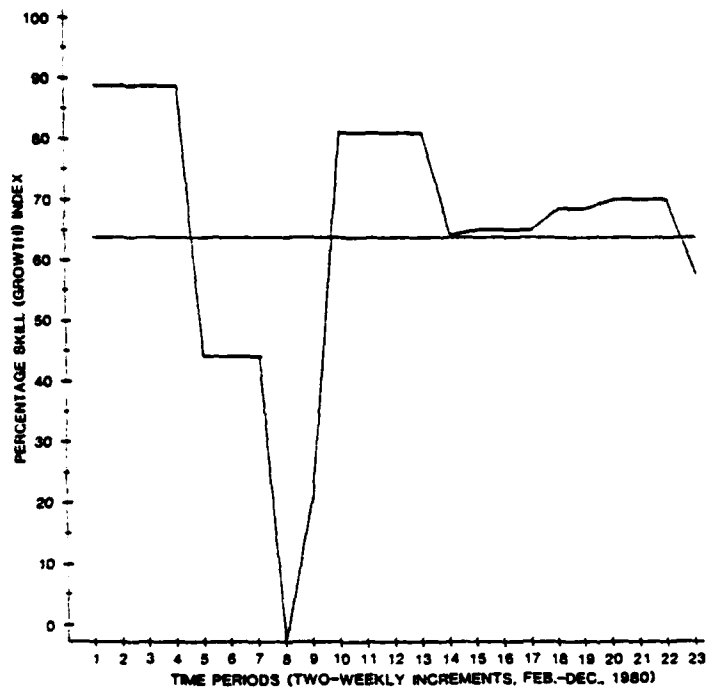


Figure 12. Skill (growth) index shown as percentage growth for MOS 41C ("C" Company).

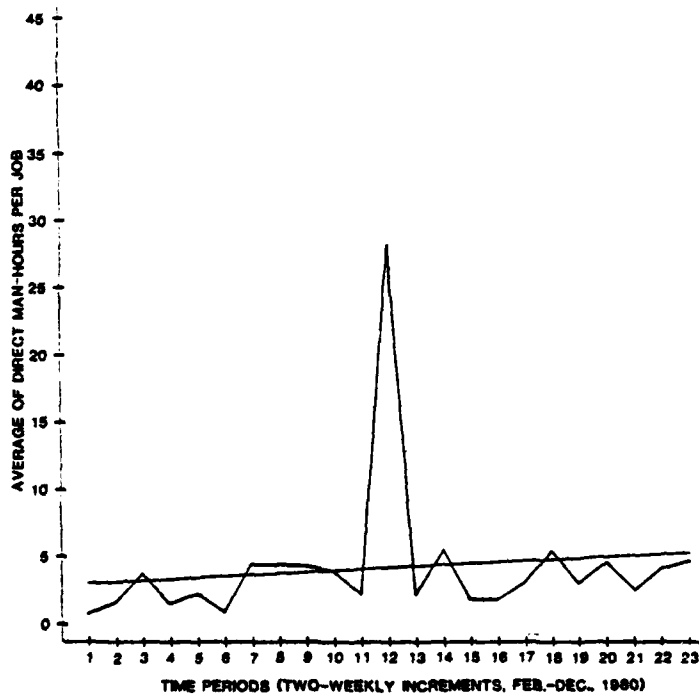


Figure 13. Average direct man-hours per job for MOS 41C ("C" Company).

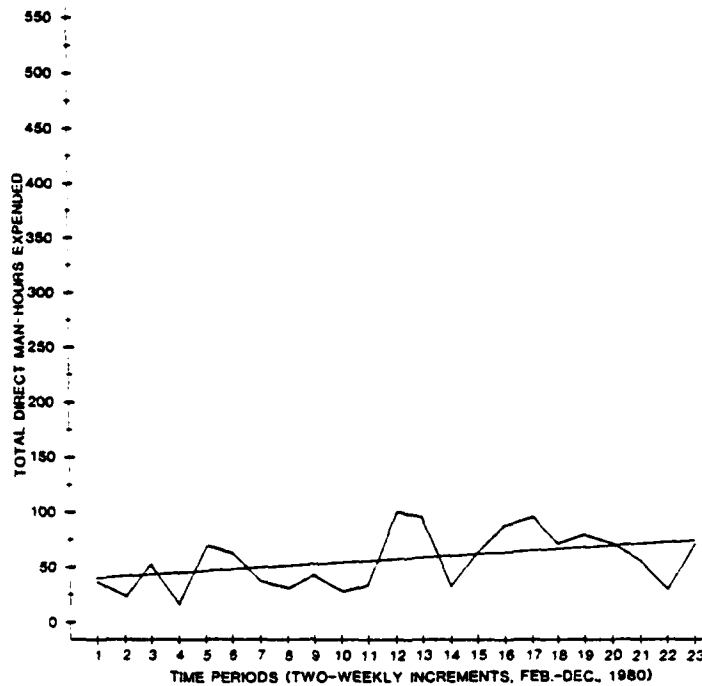


Figure 14. Total direct man-hours (shop workload) for MOS 41C ("E" Company).

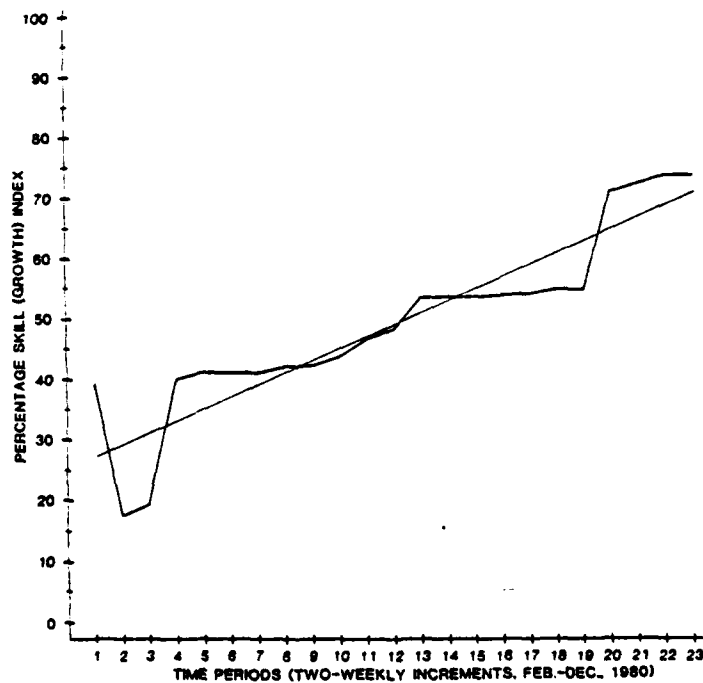


Figure 15. Skill (growth) index shown as percentage growth for MOS 41C ("E" Company).

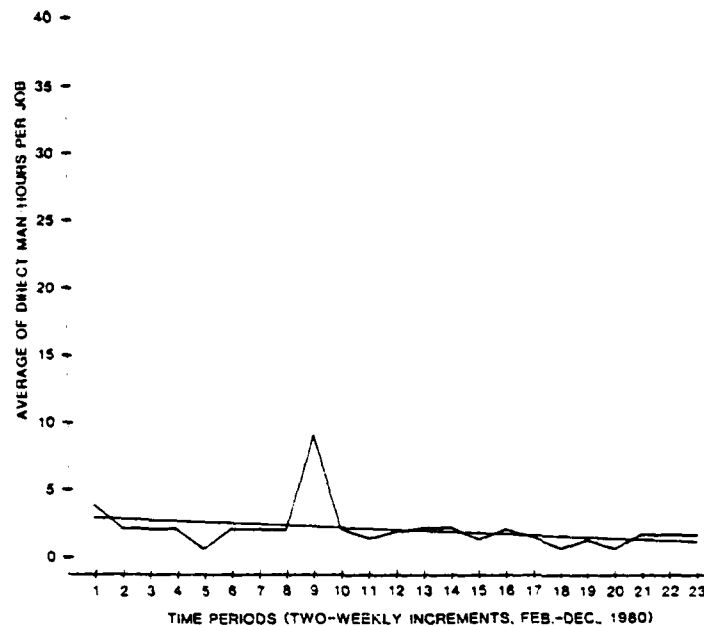


Figure 16. Average direct man-hours per job for MOS 41C ("E" Company).

average time per job will show a proportionately similar increase as that of the shop workload. There is no mediating effect from level of skill in this case.

The example for the same MOS (41C) from "E" Company illustrates the expected relationship. That is, an increase in shop workload should cause an increase in average times taken to do a job. But this latter increase is overridden by the sharp rise in level of skill causing the average time per job to actually be reduced. These conclusions are illustrated graphically in Table 3.

TABLE 3
SYMBOLIC REPRESENTATION OF INTERACTION AMONG
MEASURES FROM DECREASED WORKLOAD OF
MOS 41C (FIRE CONTROL REPAIRMAN) TASKS

COMPANY	SHOP WORKLOAD	SKILL LEVEL	AVERAGE TIME PER JOB
"C" (Figs. 11, 12, 13)	▲▲*	Stable	▲
"E" (Figs. 14, 15, 16)	▲	▲	▼▼
*KEY ▲▲, ▼▼: Medium percentage increase/decrease ▲: Small percentage increase			

Two examples from the set of trend data illustrate further the rationale clarifying the interaction between shop workload/time per job, and skill level. The examples provide comparative conditions for examining the trends derived from data for MOS 63H (automotive repairman) tasks plotted for the same February 1980-December 1980 period discussed previously.

The necessary figures illustrating the interaction are:

- "C" Company - Figure 17 - Total Direct Manhours (Shop Workload)
Figure 18 - Percent Skill Index
Figure 19 - Average Direct Manhours Per Job
- "E" Company - Figure 20 - Total Direct Manhours (Shop Workload)
Figure 21 - Percent Skill Index
Figure 22 - Average Direct Manhours Per Job

Note that in "C" Company the workload trend line decreased slightly but the skill index trend line declined drastically (from 40 to 10 percent). (This decline was probably caused by separation of repairmen with a high skill level, being replaced by apprentices with a low skill level). The average direct man-hours per job stayed constant during this period.

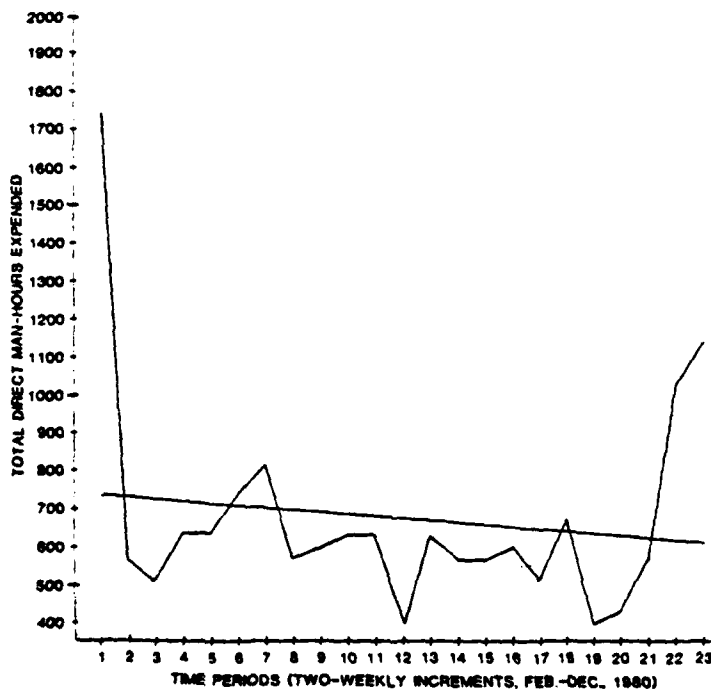


Figure 17. Total direct man-hours (shop workload) for MOS 63H ("C" Company).

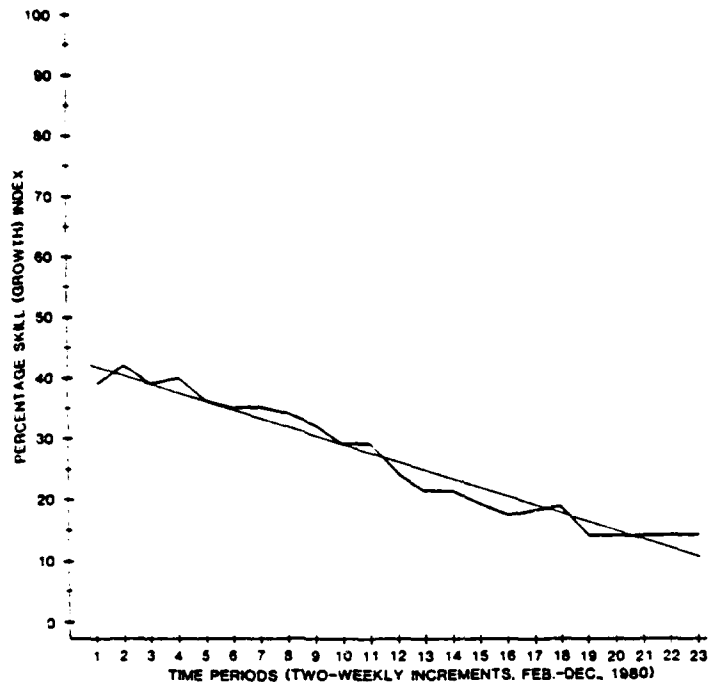


Figure 18. Skill (growth) index shown as percentage growth for MOS 63H ("C" Company).

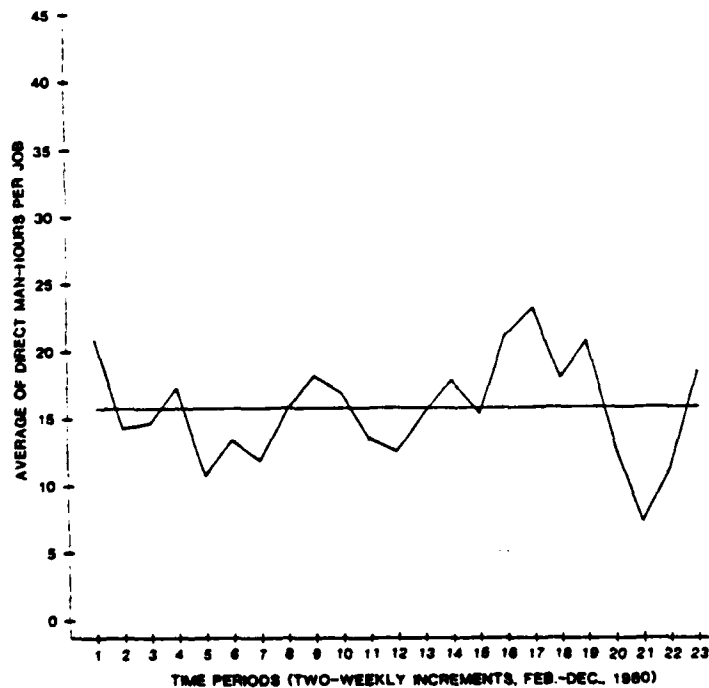


Figure 19. Average direct man-hours per job for MOS 63H ("C" Company).

Contrast these data with those for "E" Company. In this example the shop workload increased, the skill index remained constant while the average time per job increased (Figures 20, 21, and 22).

The apparent contradiction in the "E" Company data (i.e., job times rising in concert with shop workload) is because the mediating effect of skill level was **not** present and thus shop workload influenced greatly the time taken to do the work.

We are sensitive to the fact that some MOS's cited in the examples above are typically low-density MOS's and that generalizing from these cases may raise questions of reliability. It should be borne in mind that the intent here is not to evaluate maintenance in the companies which supplied the data base, nor to indirectly criticize lack of management or training actions. Our purpose was to examine the potential of the MPS to provide management data that would permit maintenance managers to assess the "state of the company" at short-term and long-term intervals. The MPS will perform this function.

We do feel that, in the future, when strong, directive and prescriptive actions are taken resulting from MPS-based diagnoses, that changes of the type cited here will be even more dramatic and will have a salutary effect on maintenance.

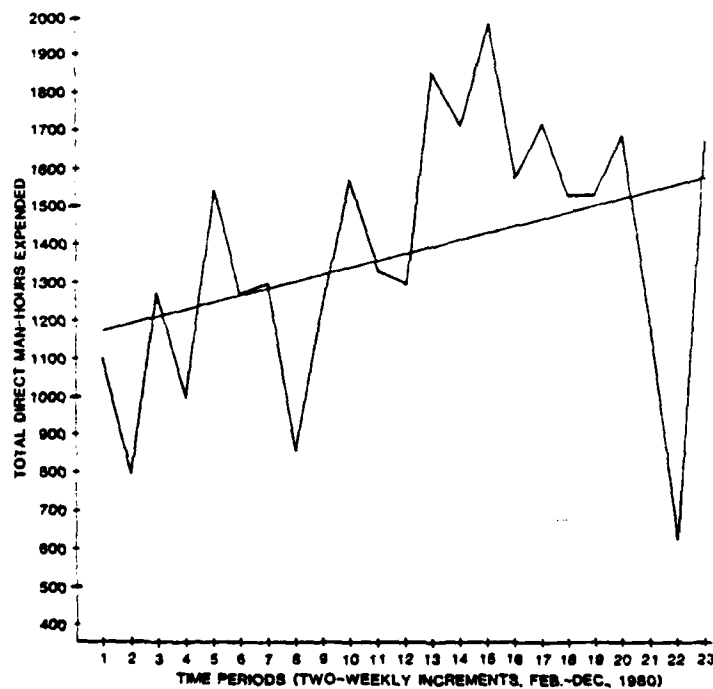


Figure 20. Total direct man-hours (shop workload) for MOS 63H ("E" Company).

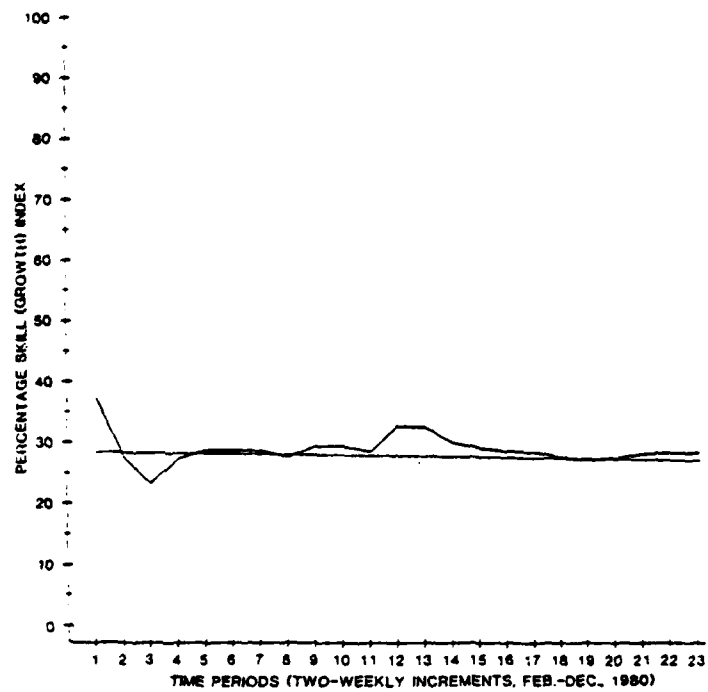


Figure 21. Skill (growth) index shown as percentage growth for MOS 63H ("E" Company).

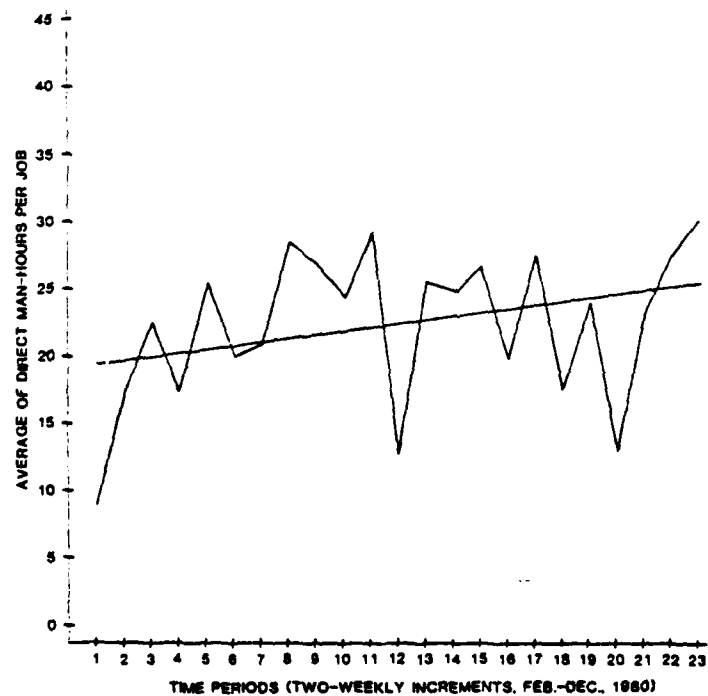


Figure 22. Average direct man-hours per job for MOS 63H ("E" Company).

ADDITIONAL EVALUATION RESULTS

During the third year a preliminary evaluation effort consisted of investigation in four major areas: correlation of measures in the prototype MPS, summary of results of a detailed user survey of MPS operation, results of skilled assessments of MPS utility by users, and preliminary results from a pilot project on false removals. These are summarized below. A detailed discussion of each is contained in Volume 1 of the First Interim Report for the third year work.¹

CORRELATION OF MEASURES IN PROTOTYPE MPS

A Pearson product-moment correlation of 33 pairs of maintenance variables for "C" and "E" companies produced a few statistically significant findings. At the time of the analysis, only 10 percent of the paired measures were considered significant at the .05 level for both companies.

The interpretation of the results gave us the first objective data reinforcing the notion that the MPS **does** have the potential for responding to changes in management policies and the results of unit-level training. The set of data drawn from operation of the prototype MPS were not, of course, measured or matched against criteria of management actions. Since the system at that time was experimental, dynamic, and subject to changes from circumstances outside our control no attempt was made to measure the effectiveness of maintenance management. The data simply demonstrated the potentiality or sensitivity of the MPS to record such change in performance as may take place over a period.

It was important that recognition was given to the complex variables which influenced the results of the correlations. These variables included: changes in personnel; weather conditions under which maintenance was being conducted; whether skilled repairmen were actually available in the shop or were detached for other duties; the availability, or not, of required tools, repair bays, and spares; and in many cases whether the customer delivered the equipment for repair with the required organizational maintenance done according to the criteria of the DSU

¹Harper, W. R. **Develop and evaluate new training and performance systems for maintenance jobs. Volume 1: MPS expansion, evaluation and related issues.** Santa Barbara, California: Anacapa Sciences, Inc., First Interim Report, September 1980.

external SOP. (A detailed discussion of the correlation pairs and the statistical results is contained in Volume 2 of the First Interim Report.²

RESULTS OF USER SURVEYS

The results of the user surveys showed positive attitudes towards the MPS and indicated general user acceptance of the prototype system. Suggestions for the final version of the MPS now operating in the field under Army jurisdiction were received during the survey and incorporated in its design. The surveys took the form of a detailed series of interviews and did not require users to complete survey protocols. The interviews dealt with operational use of the MPS printouts and interviewees opinions on training reports. The respondents included senior officers, warrant officers, and NCO's.

The time spent studying the printouts was estimated by the users to range from about 30 minutes to one hour on the average dependent on the different responsibilities, tasks, and needs for information of each user. Their overall impression was that the printouts were useful but that graphs were of limited value. The printouts were used on an interim basis for prediction of backlog estimates of shop manpower needs for FORSCOM-mandated reports. Training reports were used to determine training needs but these needs were seldom followed by specific training actions. During operation of the prototype MPS the application of courses of action by the recipients was voluntary because of the interim nature of the data and experimental character of the MPS.

The credibility of the information was assessed at about the 70 to 90 percent accuracy level for automotive data and somewhat less for Armament and C&E. All respondents agreed that the information from MPS did accomplish its aim of providing a management information system for maintenance performance.

Skilled user assessments of validity, actionability, uniqueness, and timeliness of MPS data were collected over a nine-month period at bi-weekly intervals.

² Fuller, R. G., Simpson, H. K., & Harper, W. R. **Develop and evaluate new training and performance systems for maintenance jobs. Volume 2: enhanced MPS development reference data.** Santa Barbara, California: Anacapa Sciences, Inc., First Interim Report, September 1980.

Each respondent was asked to rate the MPS on a scale of one to ten in each of the user assessment categories described above. Of the 150 responses included in the analysis, the results were strongly positive in each category.

Informal, but focused discussions were held with the Bn Cmdr, MATO, and company commanders of the 704th Divisional Maintenance Battalion on their initial impressions of the products of the newly-installed final MPS.

The Bn Cdr concentrated on reports that dealt with maintenance status and pinpointed bottlenecks. Since training reports are now generated only at six-week intervals neither he, nor his officers, had had much opportunity to use MPS-supplied training information. He noted that designated time for training without an accompanying specified need is not cost-effective. (The 704th now designate one day per week for individual technical training.) He was pleased that the MPS will define technical training needs but disappointed that MPS was limited to key technical MOS on specified technical tasks. He would like **all** training information for **all** MOS's consolidated into the MPS to avoid development of conflicting and semi-comprehensive training subsystems such as Job Books and SQT preparation.

The company commanders cited specific examples of management actions taken based on MPS reports. One dealt with manpower allocation and the other with delays in job status. Those supervisors tasked with training cited the definition of training needs and the identification of allied resources as a genuine aid to conducting effective individual training.

Although the final MPS has been radically simplified in content and format from the prototype version, comments from users were still focused on the need to keep the system simple, uncluttered, and easy to understand.

INTERIM RESULTS FROM ANALYSIS OF FALSE REMOVALS

The results were derived from data collected concerning parts needlessly or incorrectly removed as part of a DS level repair. The hypothesis behind this component of evaluation was that parts falsely removed could indicate the need for training if the repairman used parts exchange as a means of avoiding a more precise and time-consuming diagnosis of a repair problem.

A voltage regulator was chosen as representative of equipment which could be tracked through a complete sequence of repair. Each regulator's condition was always checked via a standard set of tests on arrival in the DS shop. If all tests were positive the regulator obviously should not have been removed from the vehicle and was thereby returned to service by DS repairmen. In the 20-week period of the analysis, only 22 percent (categories 1 and 2 combined) of the voltage regulators received could be construed as false removals. Table 4, following, illustrates the five categories of repair from which data were collected. Although the number in the sample (N = 165) is not inconclusive, the indications so far are that false removals should not be considered as a reliable indicator of repairman skill level.

TABLE 4
SUMMARY OF VOLTAGE REGULATOR REPAIRS

REPAIR ANALYSIS CATEGORY	TOTALS BY CATEGORY	TOTALS AS PERCENTAGE
1 Tests OK—No service needed	24	15%
2 Screw adjustment (through cover) to within 26-30V	12	7%
3 Screw adjustment (cover removed) to within 26-30V	5	3%
4 Major adjustment (replace capacitor/condenser, etc.)	34	21%
5 Discard—or forward for rebuild	<u>90</u>	<u>54%</u>
	TOTALS 165	100%

EVALUATION PLAN FOR MPS IN NEW INSTALLATIONS

BACKGROUND AND ASSUMPTIONS

The long-term plan for MPS (or a modified version thereof) is that it will be installed at other Army facilities in CONUS and USAREUR. Introduction of MPS to "new" environments thus provides a unique opportunity to build a foundation of basic data against which the effect of using MPS-derived information on maintenance performance may be judged. The required conditions are two-fold:

- **Control condition** - whereby MPS data is collected for say, three months but no output is distributed or feedback provided. In effect, a "pre-treatment" condition with typical management procedures followed (as in a non-MPS equipped company) and a typical training routine followed for each MOS (also as in any non-MPS equipped company).
- **Experimental condition** - whereby MPS output and concentrated feedback is provided to selected users who in turn investigate discrepancies in maintenance efficiency, shop productivity, and quality measures and take appropriate action. Training deficiencies are noted and investigated in like fashion. Prescriptive/remedial training programs are developed and conducted and results noted and plotted.

Since MPS does require approximately two to three months to stabilize in a totally new environment—the first condition cited above helps fulfill two major requirements simultaneously, i.e., start collection of baseline data and operational status for the MPS.

By measuring maintenance performance in a DS company with MPS installed but no feedback provided, and later comparing the results from the same company who have subsequently been provided feedback, the problem of matching subjects and conditions inherent in "between-groups" designs, is avoided. However, the pseudo "within-groups" design used in the "before/after" condition described here may still be subject to some bias from experimenter and other effects since MPS data-collection must still take place, though nominally in the "control" condition. But we expect this bias to be minimal and not significant since it will be masked by the pace and variety of events in the 'real' world of DS maintenance.

The background and procedures for each condition are described below.

INITIAL CONDITIONS (Control condition—no MPS feedback given).

The MPS outputs will reflect the current state of the real world of maintenance in the DS company where the system is installed. To interpret the outputs one must be aware of events that happened in the time period under review since they could influence maintenance performance. The MPS was designed to include "Interpretation Comments" to help users understand fluctuations in reported outputs. But evaluation concerned with MPS effect will require record-keeping of additional **influencing events**. Examples of such influencing events affecting training would include: ordered resources not arriving as scheduled; key instructor on sick call and session cancelled; or Bn. Cmdr. substituting different priorities for certain tasks.

The full benefits from MPS information can only be realized if command emphasis is focused on positive **prescriptive/remedial actions**. Actions for improving shop efficiency, productivity, and quality can usually be considered as short-term responsibilities of shop supervisors or junior officers. Command emphasis should, of course, be on long-term lasting improvements rather than on reducing maintenance "brushfires!"

Diagnosing, prescribing, and conducting training, on the other hand, is seldom a one-man operation. Since others are involved, training requires effective interaction. We therefore recommend that as part of any new MPS installation a **Training Action Committee (TAC)** be formed. We recommend the TAC has six members: the Maintenance Platoon Leader, and the WO or NCOIC heading the Automotive, Armament, Service and Recovery, Fuel and Electric, and C&E repair sections (see Figure 23).

The purpose of the TAC is three-fold:

- o To rank the needs for training actions (diagnostic) in each section against available resources;
- o To decide on mutually agreed training priorities and methods (prescriptive);
- o To review progress (results) made as a result of training actions taken.

We foresee the TAC meeting for one hour or less each two weeks. A major, but unstated, purpose of the TAC is to "persuade" individuals to make

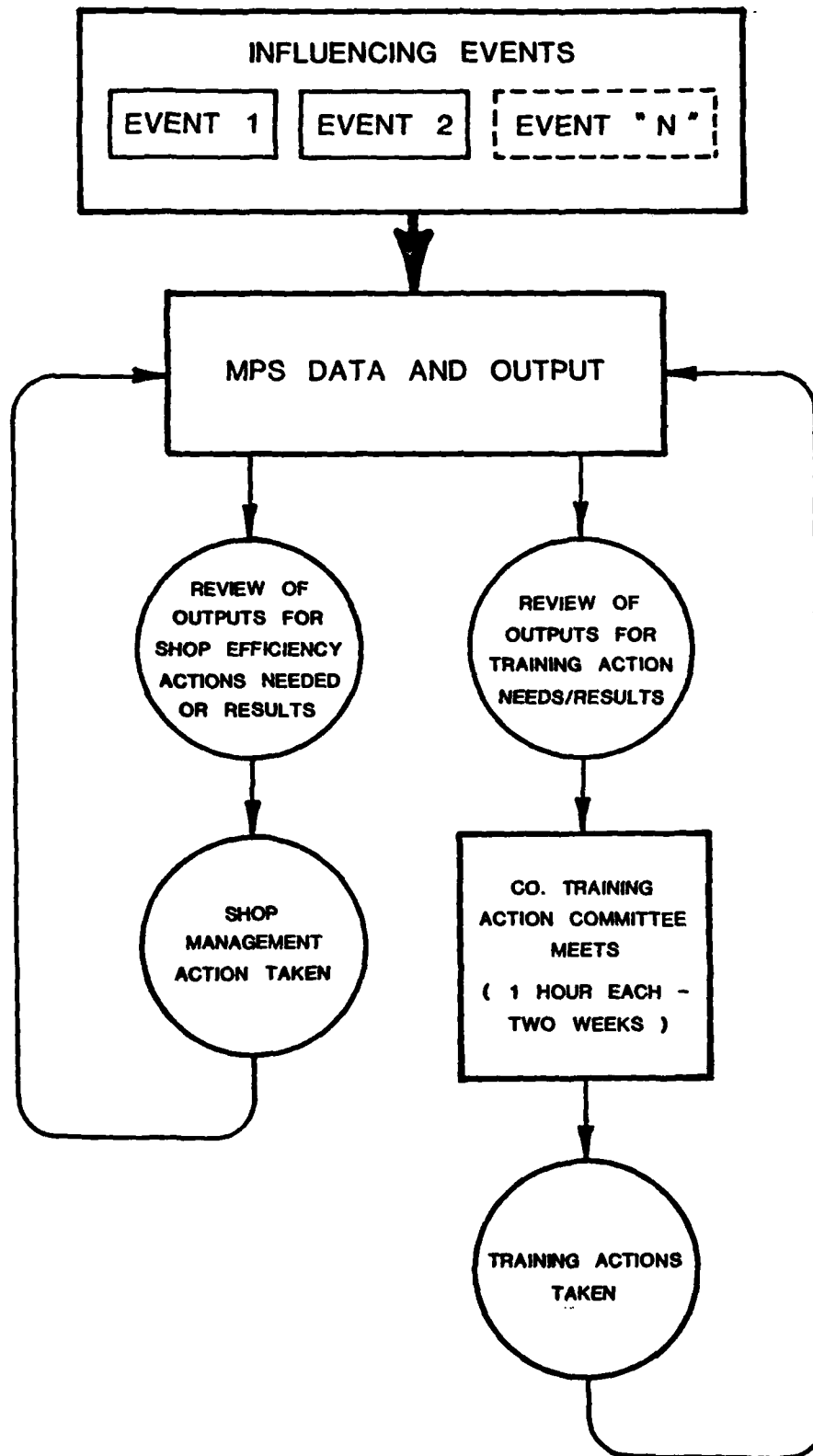


Figure 23. Flow diagram of recommended "action" sequence for MPS with Training Action Committee (TAC) appointed.

commitments to take training actions. Without actions resulting from analysis of MPS output, the system cannot be cost-effective.

PROCEDURES

The recommended procedures for establishing an evaluation plan overlap those related to system installation. To avoid redundancy the key steps in the total sequence are combined in the description below. The sequence of actions for MPS installation and collection of baseline evaluation data is shown graphically in Figure 24. Each step shown on the figure is numbered. The descriptive comments below correspond to those numbers.

1. Brief Battalion Commander and Company Officers

It is essential that the Battalion Commander, Company Commander, Shop Officer, and Maintenance Platoon Leader receive a preliminary briefing on the objectives and structure of the MPS prior to its installation in a new environment. During this briefing it should be stressed that no action will be required from any personnel for the first three months of installation. This three-month period serves the dual purpose of allowing the MPS to stabilize after installation and of starting the collection of baseline data needed as a component of the *evaluation plan*. The capability of the MPS for summarizing and tabulating maintenance performance data will be used productively from the start. Collecting baseline data also provides a test situation for the MPS under operational conditions.

2. Designate MPS Operator

It is important to stress at the outset that the operator (Army personnel) be designated as early as possible so he can become intimately familiar with the system hardware during the physical installation and connection of components.

3. Install MPS Hardware

The MPS mini-computer should be installed at this point in the sequence so any problems or internal electric faults arising from transportation handling may be diagnosed and corrected before the system is placed in operation.

4. Train MPS Operators

After the hardware is installed, the MPS operator should receive a training course on operation of the mini-computer and on those components of the MPS

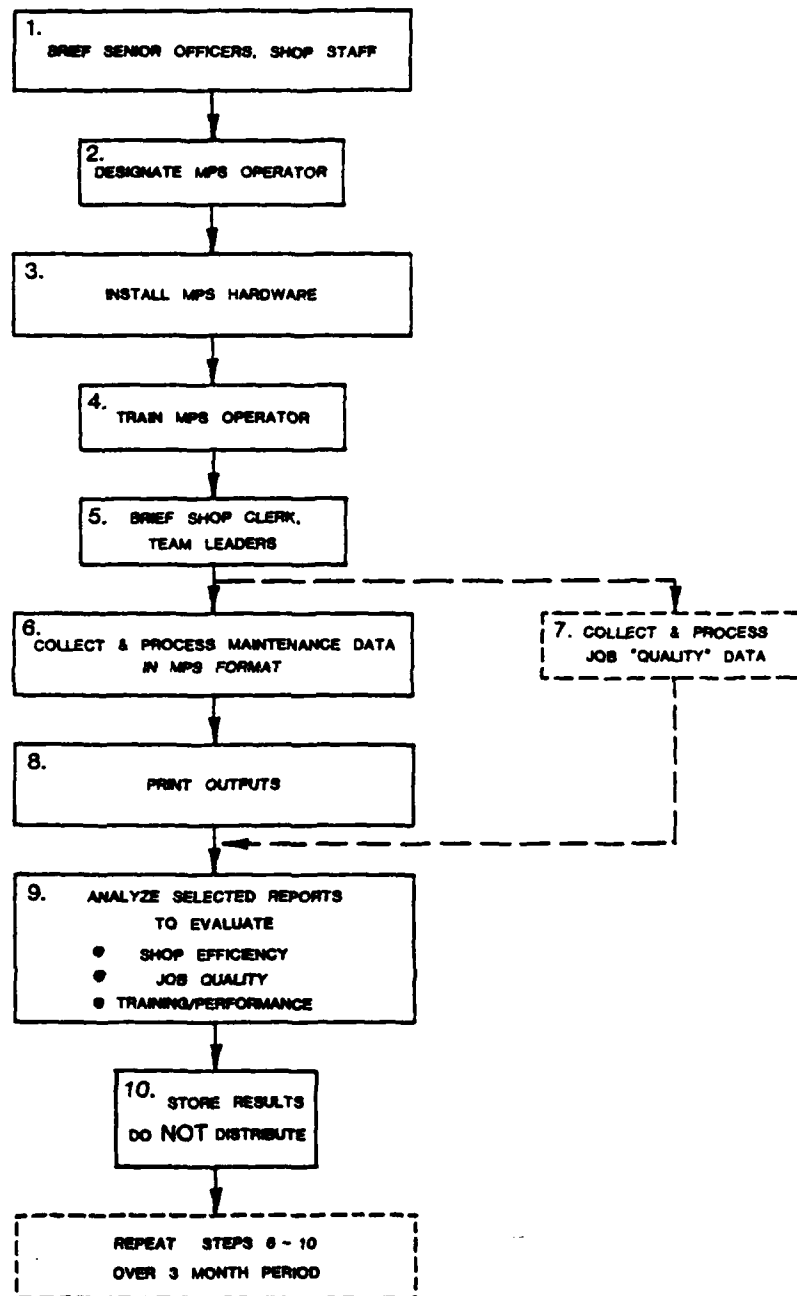


Figure 24. Action sequence for MPS installation and collection of baseline evaluation data.

designated as operator responsibilities. The training course should follow the pattern developed for training of the final system operators in use at Fort Carson, Colorado.

5. Brief Shop Personnel

The shop clerk plays an important role in MPS data collection. The shop clerk, team leaders and shop foremen from each technical section should be briefed on their responsibilities in providing data inputs for the MPS. Examples should be provided of the special data collection forms at this time. The importance of the role of these men in system operation should be emphasized.

6. Collect and Process Maintenance Data

Data collection should start on a predesignated date under control of the MPS operator and his designated supervisor. Inevitably mistakes, errors, and omissions will occur during the initial familiarization with the data collection component of MPS operation. Collected data will require careful inspection and editing before entry to correct these errors before processing.

7. Collect and Process Job Quality Data

Any evaluation involving productivity or efficiency has to be made against criteria of job quality. These data will be used later during the analytical component of evaluation to qualify outputs relating to shop efficiency and productivity.

We recommend development of a **job quality rating form**. This form would include: scales against which the inspector could rate accuracy of work done on the job; whether job was completed to required tolerances, clearances; a rating of the operability of the equipment after repair; and general cleanliness and condition of the finished work. The total of these ratings could be averaged to represent the job quality rating.

8. Print MPS Outputs

The outputs from the processed collected data should be printed and retained by the MPS operator/supervisor for analytical purposes. These outputs **should not be distributed at this time** since this initial period of MPS operation is being used to establish a baseline against which the effect of MPS on maintenance performance will eventually be measured.

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9. Analyze Selected Outputs

The MPS outputs will be used to evaluate:

- Shop efficiency. The measures used will be:
 - Average direct man-hours per job (MPS Table 2)
 - Total direct man-hours expended per period (MPS Table 1)
 - Average days spent in selected statuses (MPS Table 5)
- Job quality. Job quality is best evaluated by the specialist who performs final inspections.
- Training/Performance. The measures used will be:
 - Skill growth index and skill development summary (MPS Table 6 and MPS Table 7) by periods
 - The number of hours of technical training in the company per period (special record)
 - The usage of training resource material averaged over each period (special record)
 - The number of repairmen passing technical components of SQT (special record) related to the period covered by MPS

The results of these evaluations and analyses would be stored and not distributed during the initial stabilization and baseline data collection period. The sequence of Steps 6 through 10 (as shown on Figure 24) would be repeated at two-week intervals over a three-month period.

FULLY OPERATIONAL CONDITION

The procedures for MPS evaluation when the system is fully operational (i.e., after the three-month installation and stabilization period has elapsed) is illustrated graphically in Figure 25 . Steps 1 through 5 are repeated.

However, an important change from the "initial condition" sequence is that **user outputs are distributed** (Step 4) and that we assume a key condition of successful MPS operation has been met, i.e., **user action was taken** (Step 5). This step represents actions taken as a result of information gained from the MPS reports. When user action is taken the effect should be felt on the MPS data base in terms of enhancement of training, improved proficiency, improved quality of jobs, and improved productivity.

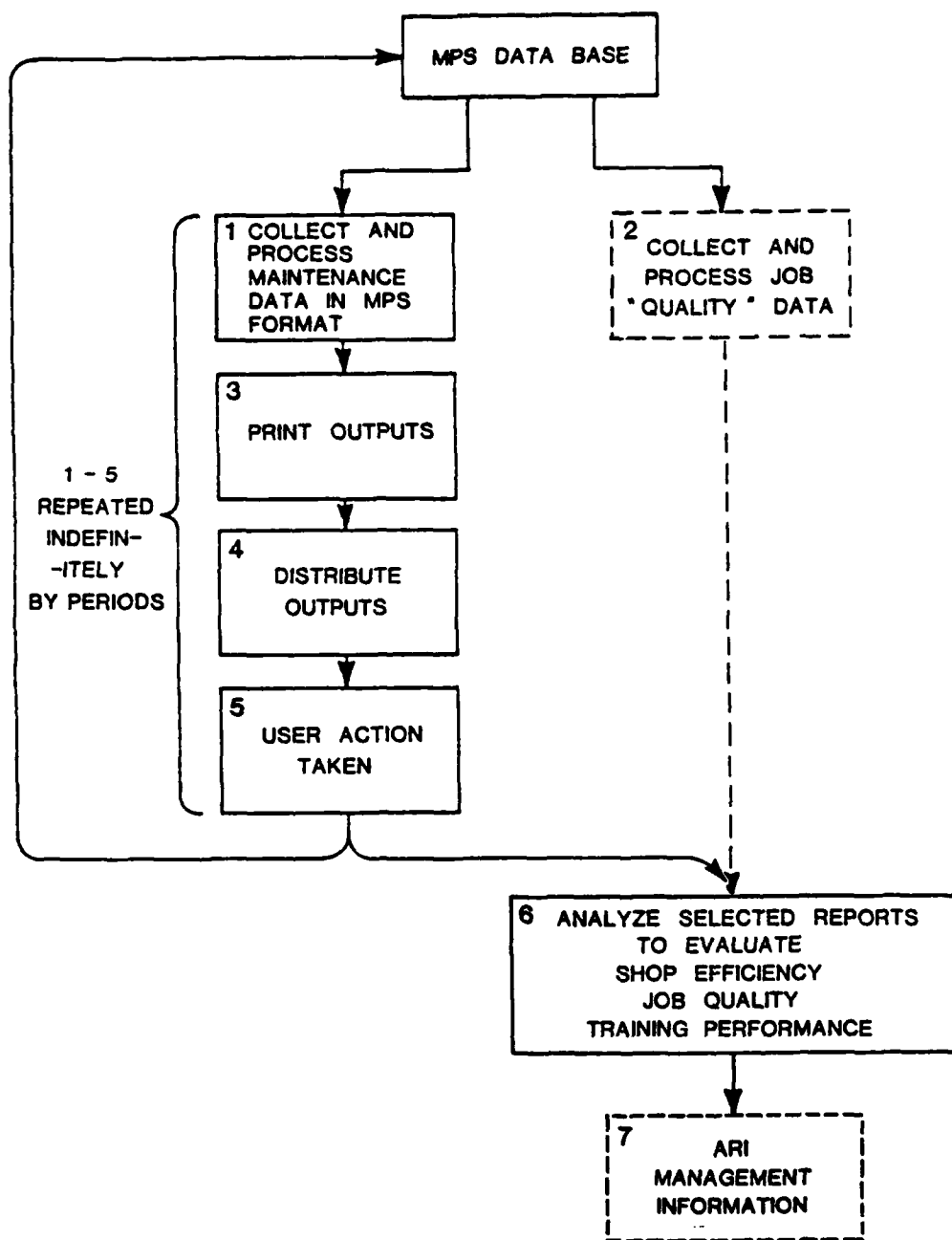


Figure 25. Action sequence for MPS evaluation of fully operational system.

The MPS supervisor and other users should be able to plot or tabulate the effects of MPS on maintenance performance. The same type of measures (Steps 6/7-Figure 25) as those listed in the section dealing with MPS installation and baseline evaluation (Steps 9/10-Figure 24) would be used to measure these effects. By comparison of operational data with the data obtained from the baseline report, the investigator should be able to describe a difference between the non-MPS information distribution condition and the results shown in changes in maintenance performance after MPS feedback was provided. The results of this evaluation of the effect of MPS on maintenance performance would be used for ARI project management information. The MPS, of course, would be used at this time by maintenance managers to improve their maintenance decision-making.

MPS EFFECTIVENESS SCENARIOS

If actions are taken based on diagnoses and prescriptions contained in MPS training reports, dramatic improvements in maintenance performance can be gained. Figure 26 illustrates in conceptual form the type of improvement that could result from the enhancement of repair skills. Unfortunately, the final MPS has not been in operation in field conditions under Army jurisdiction long enough for training actions to affect the maintenance performance data base. However, the sample scenarios provided below illustrate the impact of training and skill enhancement on maintenance. (The assumptions governing the computation are listed.)

SCENARIO 1 (Fiscal Gains From Shorter Job Times)

- Assume that each of the four tank battalions in the 4th Infantry Division (Mechanized) averages two tank repair jobs requiring DS assistance per week over one year. This represents a total of 416 tank repair jobs.
- Assume that an "average" repairman (i.e., a man in paygrade E4 with over two years service) earns \$8.50 per hour.

BASIS	Base Pay	= \$	637.50	per month
	Housing allowance	=	206.10	per month
	Rations	=	<u>118.20</u>	<u>per month</u>
	Total	=	961.80	
	Est. Overhead @ 80%	=	510.00	
	Monthly Total	=	1,471.80	
	Yearly Total	=	\$17,661.80	
	(No. of working hours per year	=	2,080)	

- Actual MPS data representing a 46-week period for a forward support DS company show the ratio of direct to assigned labor hours as 40.6 percent (40.6 percent of a possible 2,080 hours = 844 hours). This represents an average repairman's true hourly rate of \$20.91 (i.e., \$17,661.80 ÷ 844).
- Assume that by enhanced skill resulting from MPS-prescribed training the repairman can complete each tank job one hour faster on the average, thus saving 416 direct labor hours per year. Since tank jobs are usually done by three-man teams the savings in time is 1,248 hours per year. **The dollar savings illustrated here would total \$20.91 x 1,248 = \$26,095.68.**

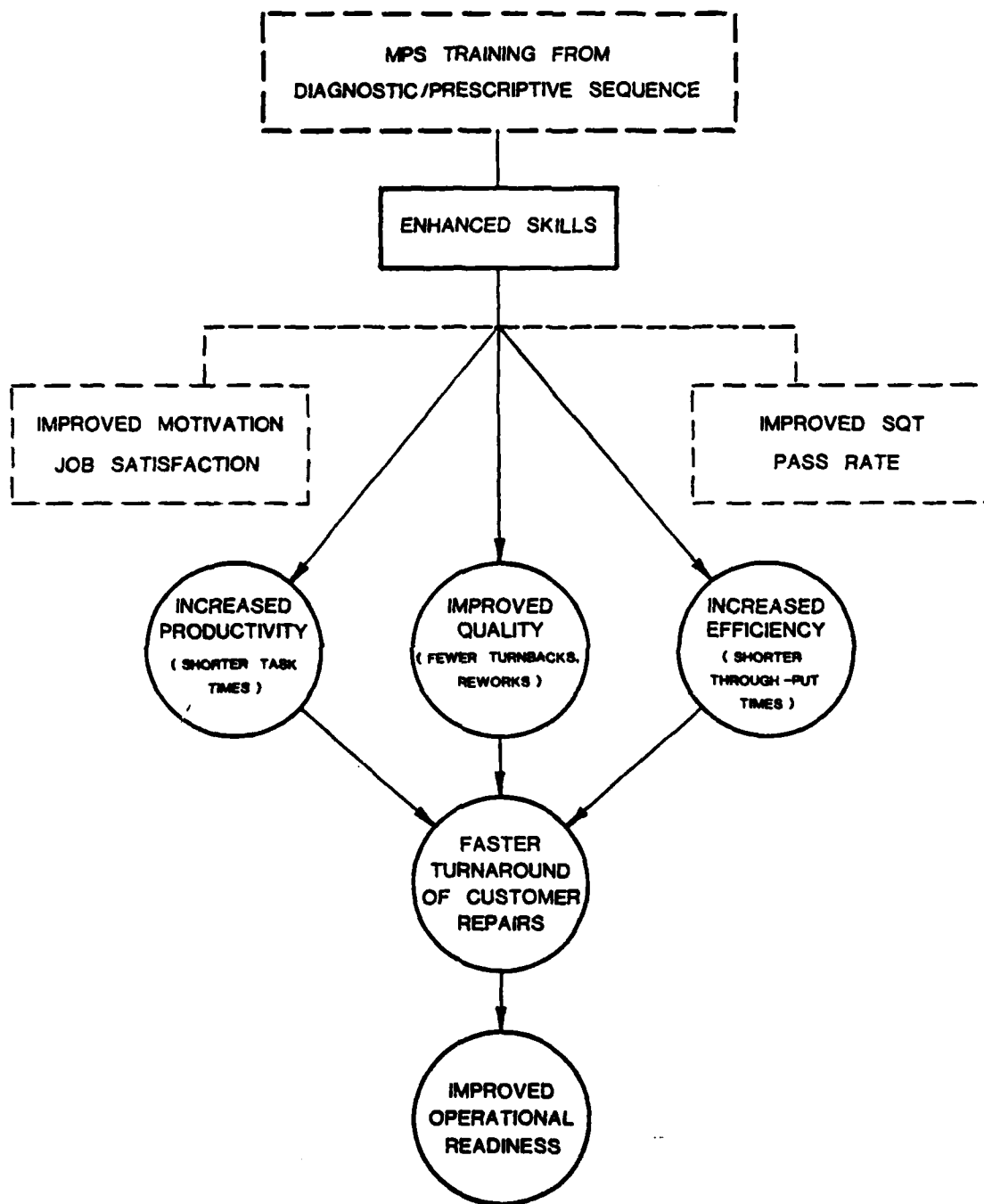


Figure 26. Results possible from enhancement of individual performance.

NOTE: This scenario is based on two automotive (track vehicle) repairs per week done by one MOS (63H). Consider the potential savings if **all ten MOS** listed in the MPS were able to realize similar savings on **all** repair jobs.

SCENARIO 2: (Fiscal Gains From Reduction In False Removals)

- In ARI Research Problem and Review report 79-8³ the authors concluded that the rate of false removals in Organizational level maintenance was 42 percent.
- Assume that the rate of false removals in DS maintenance is somewhat less, say 30 percent. In other words, of every \$100,000 spent on spare parts, \$30,000 is spent unnecessarily. The MATO office, 704th Division Maintenance Battalion, estimates their FY cost for DS repair parts as \$900,000.00. Thus the cost of false removals at the DS level based on these figures equals \$270,000 per year.
- Assume that by improved diagnostic procedures and familiarization with the equipment resulting from training actions based on MPS reports, that false removals could be reduced. A five percent reduction would represent a savings of \$13,500 per year. **Reducing false removals to a 20 percent rate (from 30 percent) would save \$27,000 per year.**

NOTE: As reported elsewhere, a system for gathering false removal data at the DS level was set up in 1980 to help evaluate skills in diagnosis of faults in a selected equipment item. Because of diagnostic equipment breakdowns, data collection has been erratic.

The figures used in the scenario are deliberately biased toward a conservative approach in computing possible savings.

SCENARIO 3: (Improvement of Turnaround Time (TAT) Index)

- AR 750-1⁴ describes a formula for a TAT index based on a criterion of a turnaround time of 26 days. The formula is:

³Dressel J. D. & Shields, J. **Organizational Maintenance Performance** (Research Problem Review 79-8). Washington, DC: U.S. Army Research Institute for the Behavioral and Social Sciences, April 1979.

⁴Department of the Army. **Army Materiel Maintenance Concepts and Policies** (AR 750-1). Washington, DC: April 1978.

$$\text{TAT index} = \frac{\text{Number of jobs completed in 26 days or less}}{\text{Total number of jobs completed during report period}}$$

- The DA objective (for DS units) is to complete 75 percent of jobs within 26 days. The minimum acceptable level is set at 70 percent, i.e., 70 percent of jobs should be completed within 26 days.
- An average years workload for a typical DS company for M60 and M35A2 repairs is 418 jobs (based on actual MPS data).
- To meet the TAT criterion, 315 jobs would have to be completed in 26 days (i.e., $\frac{315}{418} \times 100 = 75.3$ percent).
- Assume that a DS company has a TAT index of 72.4 percent (303 jobs) and wishes to improve turnaround time to meet the DA objective.
- Assume also that by intensive management action based on MPS shop efficiency and productivity reports, one additional job per month (a total of 12 per year) could be turned around in 26 days or less. The **TAT index would thus rise above the objective (i.e., $303 + 12 = 315$)**

$$\frac{315}{418} = 75.3 \text{ percent}$$

NOTE: This example cites figures for a sample of automotive maintenance jobs done by only one DS company. Consider the improvement in the Divisional Maintenance Battalion TAT index if **all** jobs in all technical areas were subjected to similar management actions and showed similar improvements.